Unit 3

Material

In Level I, you learnt about the basic assessment of an automobile and its components. This unit will discuss the material used to make these components and its manufacturing methods.

SESSION 1: ENGINEERING MATERIAL

We hear a lot about the parts that make up a vehicle, such as engines, transmissions, seats, HVAC (ventilation, air conditioning and heating) systems, and so on. But have you ever thought what material is used to make them?

The automobile industry uses various material, such as, iron, aluminium, plastic, glass, steel, rubber, petroleum products copper, etc., to produce different components, such as dashboard, transmission gears or the engine block.

Classification of Engineering Material

This material is available with spacious range of properties and characteristics. There are many properties, which are inherent in the material and some of them can be changed during processing and manufacturing.

Engineering material can be classified into two category—metals and non-metals (Fig.3.1).

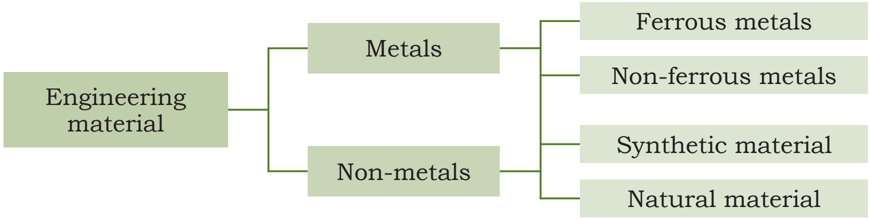

Fig. 3.1: Engineering materials

Metals

Metals are the most commonly used engineering material. They can be further classified into non-ferrous and ferrous metals.

Ferrous metals

When metal or alloy contains iron, it is known as ferrous metal. Ferrous metals are durable and strong hence used in applications that require tensility at a relatively low cost. These metals are used in making tools, vehicle engines, pipelines, automobiles, bridges, etc. Fig.3.2 shows the family of ferrous material.

Carbon steel

Many sophisticated alloys have been developed in the recent years but steel seems to remain the most commonly used engineering material. Steel is an alloy of carbon and iron and contains less than 2% carbon. Steels containing about 0.03% to 1.2% carbon are called plain carbon steels. Besides carbon, it also contains silicon, manganese, sulphur and phosphorous.

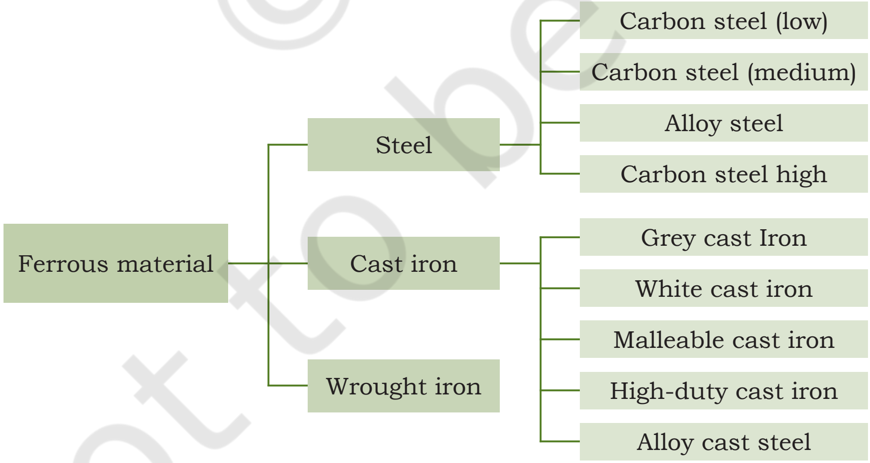

Fig. 3.2: Family of ferrous material

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Dead mild steel

Steels containing up to 0.15% carbon are called dead mild steel. It is a soft and highly ductile material and can be easily formed. Car bodies, deep drawn components, tinplate, nails, rivets, thin wires, etc., are made from dead mild steel.

Mild steel

It contains approximately 0.15–0.3 % carbon, making it malleable and ductile. Mild steel has a relatively low tensile strength but it is cheap and easy to form. It is used for making structural members, shaft, levers, screws, nails, wires screws, etc. Mild steel is coated with tin to make cans for food and beverages.

Medium carbon steel

It is also called constructional steel. Medium carbon steel contains carbon from 0.4–0.6 %. It is strong, heat treatable, and thus has wide range of properties in the quenched and tempered state. It is used for applications where strength and toughness are required. Fasteners, shafts, axles, crankshafts, connecting rods, gears, wire ropes, rails, etc., are made using medium carbon steels.

High carbon steel

Any steel with, 0.7–1.2 % carbon called high carbon steel. It has the highest hardness and toughness of the carbon steels and the lowest ductility. They are wear resistant and therefore always hardened and tempered. It is used to make machine tools, cold chisels, axes, dies, taps, drills and saws, hammers razors, etc.

The main limitations of the plain carbon steels in engineering applications are:

1. High strength steel can be obtained by having high carbon contents, which makes it brittle. It is not possible to achieve high strength with high ductility and toughness.
2. Hardening requires rapid cooling rate, which can lead to distortions and cracking during quenching operations.
3. Large sections cannot be hardened uniformly due to variation in cooling rate.

4. Plain carbon steels have poor resistance to corrosion and oxidation at high temperatures.

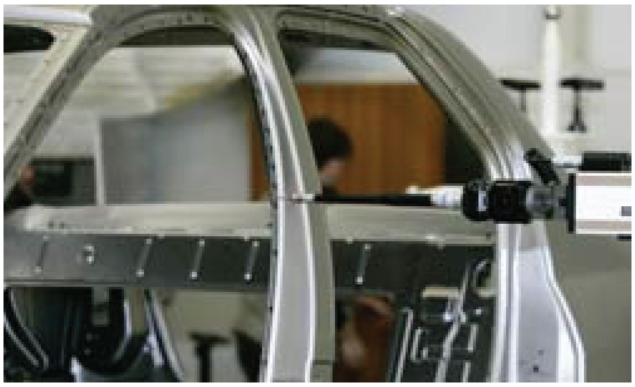
Fig. 3.3: Use of steel in car

Small and medium carbon steel is used for constructional works and structural and high carbon steel is used for manufacturing tools and components, which need to be wear-resistant and hard.

In cars (Fig.3.3), steel is used to build a cage beneath the chassis that forms the skeleton of the vehicle and protects the occupants in the event of a crash. In most cars, door beams, roofs and body panels are also made by using steel.

Steel manufacturing is evolved, and so carmakers these days have been creating different types of steel for dissimilar areas of the vehicle that are crumple to rigid or that can absorb changed impacts.

Table below describes the uses of plain carbon steel in different component in material.

Alloy steel

Alloy steel is steel that is alloyed with several elements, such as manganese, silicon, metal, titanium, copper, chromium and aluminium to enhance its properties. For example, stainless steel is an alloy steel in which nickel and chromium are added in various proportion to make plain carbon steel.

Various alloys, such as increased hardness, corrosion resistance, strength, improved formability (ductility) and weldability. Alloy steels can be classified into three categories: low alloy steels, which contain up to 5% alloying elements; and high alloy steel, which contains more than 10% alloying elements.

Alloy steels is used in exhaust silencers and catalytic converters, pillars of car doors, bus bodies, fuel union components, shafts, motorcycle frames, bicycle rims, motorcycle wheel rims, etc.

High-strength low alloy steel (HSLA)

High-strength low alloy steel is a type of alloy steel that provides better mechanical properties than carbon

Fig. 3.4: Cylinder head made of cast iron

steel. With 0.05%–0.25% carbon. It can be easily formed and welded. It is used in automobiles, bridges, roller coasters and other structures that are designed to handle large amounts of stress or need a good strength-to-weight ratio. HSLA steels are mostly 20% to 30% lighter in weight than carbon steel of similar strength.

Cast irons

An allow of iron containing 2% and 4 % carbon along with silicon, manganese, sulphur and phosphorus chemical supplement, is called cast iron.

With its relatively low melting point, good castability, rigidity, fluidity, cast iron has become an engineering material with a wide range of applications. Many products such as pipes, machine castings, ornamental castings, casings and blocks of many automobile and tractor assemblies, heavy parts not subjected to tension or shock loads, agricultural machine parts, etc., are made of cast iron.

They are four basic types of cast irons, which are as follows:

Grey cast iron

The grey cast iron when fractured, has a grey appearance and a graphite smudge, which can usually be obtained on the finger, when rubbed on the surface. The grey cast iron has a composition of 2.5%–4% carbon, 1%–3% silicon, 0.4%–1.0% manganese, 0.15%-1% phosphorus and 0.1% sulphur.

Grey cast iron has excellent compressive strength, machinability, and vibration damping characteristics. It is wear and corrosion resistant, which makes it a good choice for casting applications. Grey cast iron is used to make automobile engines, cylinders blocks, cylinder head, gear box case, flywheels, crank case and pistons, machine castings, machine tool beds, etc.

White cast iron
The fast cooling of iron with 2% – 4.3 % carbon produces white cast iron. Due to the presence of a large amount of iron carbide, it is brittle and hard; and finds applications where abrasion resistance is required.

Malleable cast iron
It is essentially white cast iron, which has been modified by heat treatment. It is formed when white cast iron is heated to around 920 °C and then left to cool very slowly. It has good tensile strength, excellent impact strength, corrosion resistance and match inability. It can be used for making axle bearings, track wheels, automotive crankshafts, etc.

Spheroidal graphite cast iron
Also called nodular cast iron or ductile cast iron, spheroidal graphite cast iron has graphite present in it as tiny spheres or nodules. It is produced by adding magnesium or cerium to iron before casting. The nodular cast iron is more ductile and strong than grey cast iron. The combination of high ductility, strength, and cast ability makes ductile cast iron a rather attractive engineering material. It finds application in creation of gears, camshafts, crankshafts, etc.

Alloy cast iron
It contains alloying elements, such as nickel, chromium, molybdenum, vanadium copper, etc., to increase the strength or facilitate heat treatment.

The composition and uses of some typical cast irons are given in Table 3.1.

Table 3.1: Uses of cast irons

Composition (in %)					
C	**Si**	**Mn**	**S**	**P**	**Uses**
3.50	1.15	0.8	0.07	0.10	Heat-resisting castings and ingot moulds
3.30	1.90	0.65	0.08	0.15	Automobile brake drums
3.25	2.25	0.65	0.10	0.15	Automobile cylinders and pistons
3.25	2.25	0.50	0.10	0.35	Light machine castings
3.25	1.75	0.50	0.10	0.35	Medium machine castings

3.25	1.25	0.50	0.10	0.35	Heavy machine castings
3.60	1.75	0.50	0.10	0.80	Light and medium water pipes
3.40	1.40	0.50	0.10	0.80	Heavy water pipes
3.50	2.75	0.50	0.10	0.90	Ornamental castings requiring low strength-now obsolete

Wrought iron

Wrought iron is an iron alloy containing about 0.03% carbon and up to 1.8% impurities, which are mainly slag. It is extremely tough, malleable and ductile and can be easily formed and joined by forge welding. Due to its relatively low strength, it is mainly used for decorative and architectural iron works, such as for making railings, outdoor stairs, fences and gates, nuts and bolts, handrails, etc.

Non-ferrous Metals and Alloys

Non-ferrous metals are pure metals. These metals and alloys are used due to their desirable properties, such as corrosion resistance, thermal and electrical conductivity. However, these are not used as structural materials due to low mechanical strength.

Copper alloys, such as bronze, are corrosion resistant, strong, and machinable and have high melting points. These are used in making valve components of steam and hydraulic machines and in marine applications.

Brass is another important alloy of copper, which can be easily formed to shape. Brass is used in the

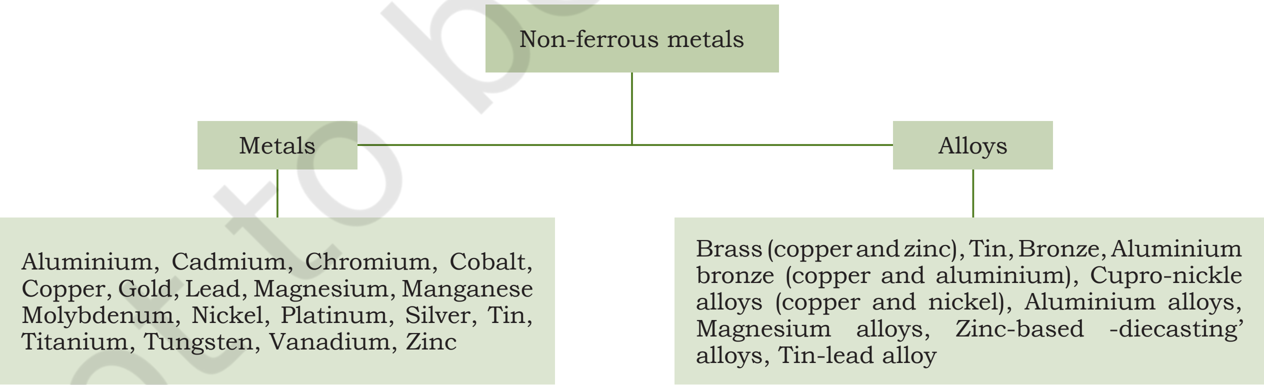
Non-ferrous metals
Metals
Alloys
Aluminium, Cadmium, Chromium, Cobalt, Copper, Gold, Lead, Magnesium, Manganese Molybdenum, Nickel, Platinum, Silver, Tin, Titanium, Tungsten, Vanadium, Zinc
Brass (copper and zinc), Tin, Bronze, Aluminium bronze (copper and aluminium), Cupro-nickle alloys (copper and nickel), Aluminium alloys, Magnesium alloys, Zinc-based -diecasting' alloys, Tin-lead alloy

Fig. 3.5: Family of non-ferrous material

manufacturing of electrical components, domestic water fittings and plant protection equipment.

Aluminium alloys have become important engineering materials due to their lightweight, corrosion resistance and fairly good strength properties. They are widely used in aircraft, electrical and automobile industries, and to limited extent in farm machines.

Fig.3.5 shows the family of non-ferrous materials.

Some important non-ferrous metals and alloys used in automobiles have been given below.

Aluminium

Aluminium has been used to manufacture automobiles for many years. High specific energy density and good specific strength are its most important properties. It is recyclable and corrosion-resistant too. However, it cannot replace steel parts of auto components. Nowadays, aluminium is being used to make vehicle covers, power trains, and air conditioning body structure. Aluminium castings have been constructive to a variety of automobile parts for a long period. In automotive power train, aluminium castings have been used for roughly percentage of pistons, cylinder heads, 85% about 75% of intake manifolds and transmission (other parts-rear axle, and drive shafts, etc.) For chassis applications, aluminium castings are used for about 40% of wheels, for bracket, brake apparatus, suspension (control arms, supports), steering components (air bag supports, steering shafts, knuckles, housings, wheels) and instrument panels. Developments in this sector have demonstrated that up to 50% weight saving can be achieved by the replacing of steel by aluminium. 20%–30% of total vehicle weight decreases may also be achieved to other reduction opportunity.

Magnesium

Magnesium is the lightest metallic construction material that is used in automotive engineering. Magnesium is 33% lighter than aluminium and 75% lighter than steel or cast-iron apparatus. The corrosion resistance of magnesium alloys is also superior than that of traditional aluminium die-cast alloys. Therefore, development in

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magnesium alloys, and coating technologies have made it a strong, lightweight and cast-effective solution of communication housings or parts of bonnets and doors for lightweight cars.

Copper and brass

Copper, brass and additional copper-based alloys meet the requirements of electrical conductivity, durability and strength in automobile. The average car contains approximately 23 kilograms (including 18 kilograms of electrical components). Copper and brass together make about 1 to 2% of a vehicles weight. It is expected that "hybrid vehicles" will use almost double the amount of copper (approx. 45 kg) approximation to that of traditional vehicles. Over the next few years, new copper-brass car and truck radiators that could last ten years will debut in the automotive industry. They will replace aluminium components of today's vehicle. Radiators are 35%–40% lesser in weight and correspondingly lower in material costs. Brass's valuable properties and relative ease of production has made it one of the most widely used alloys. Nuts, bolts, threaded parts, terminals, jets, taps, injectors, valve bodies, pipe and water fittings, parts of transmission, bushing, etc., are made from brass.

Synthetic Material

Fig.3.6 shows the categorisation of synthetic material. Plastics and composites have found their use in today's automobile. Some of them have been explained below.

Plastics

Plastics, a key material used in the automotive industry, is lightweight, corrosion resistant, flexible, durable and gives high performance at low costs. The properties of plastic can be improved through chemical.

Let us look at the advantages of using plastic in the automobile industry:

- It is durable, and impact-resistant and corrosion-resistant.
- It is flexible, allowing freedom in designing and mixing of components.
- It is inexpensive.

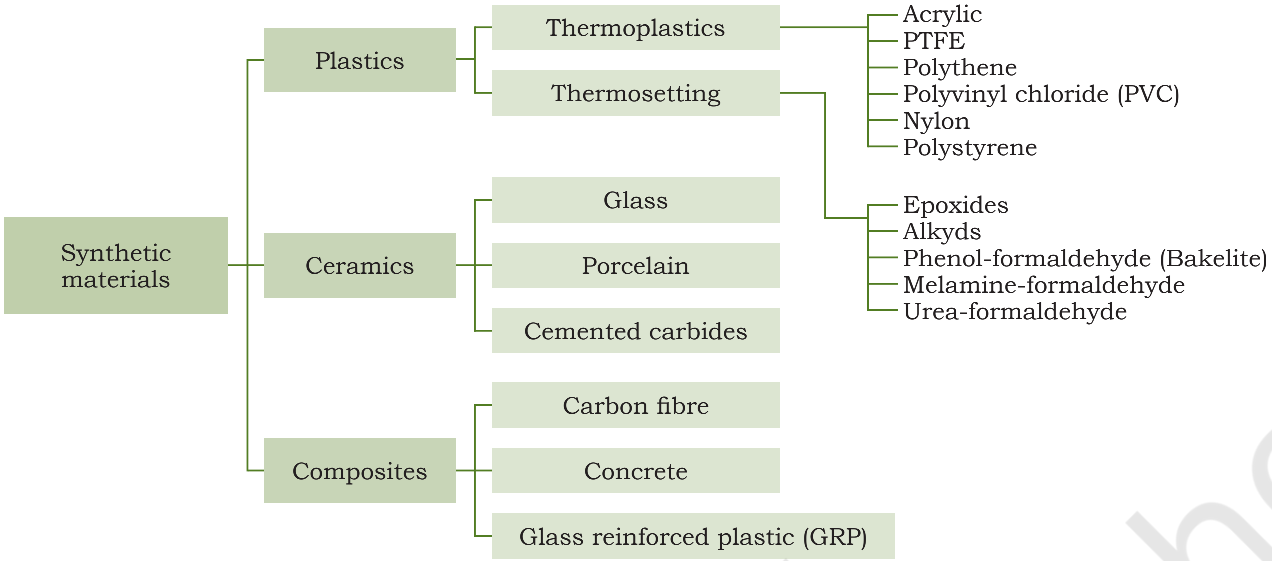


Fig. 3.6: Family of synthetic material

- It is light-weight, which leads to energy saving and subsequently lesser pollution.

In 1984, average new car contained 8.5% plastics by weight and today similar car contains around 11% plastics. The increased use of plastics reduces the mass of vehicles and consequently emissions. A quick look inside any model of the car may show that plastics are now used in both exterior and interior components, such as bumpers, doors, safety and windows, headlight and side-view mirror housing, trunk lids, engine intake manifolds, fuel tanks, steering wheels, interior door panels, built-in speaker baffles, door handles, wheel covers, dashboards, hoods, grills, gauges, dials, switches, air conditioner vents, floor mats, seat belts, airbags, wheel covers, etc. (Fig.3.7).

Fibre-reinforced plastic (FRP)

It is a composite material made of a polymer matrix reinforced with fibres. A mould is used to create the complete product (FRP), fiberglass is normally thermo set with a type of plastic or epoxy resin. When cured, the end product will hold its shape because of the resin, even as the fiberglass will provide strength and stiffness. FRPs are frequently used in the

Fig. 3.7: Use of plastic

aerospace, automotive, marine, building industries and ballistic armor. It is used in bodies of racing cars to decrease weight, front show, inner windows, rear show, bumper, engine cover, etc.

Fig. 3.8: Rubber tyres

Rubber

What's the common thing among all automobiles? They all require tyres. Rubber is impotent component and it used to manufacture various part such as special tyres, parts, wiper blades, engine mounts, seals, hoses and belts, etc. Automobile manufacturing is the base of the rubber industry, as about 75% of the world's usual rubber production is used to make tyres for vehicles. Compare with the plastic, it is very durable and cheap. Rubber is bendable material that has a wide uses in automobiles.

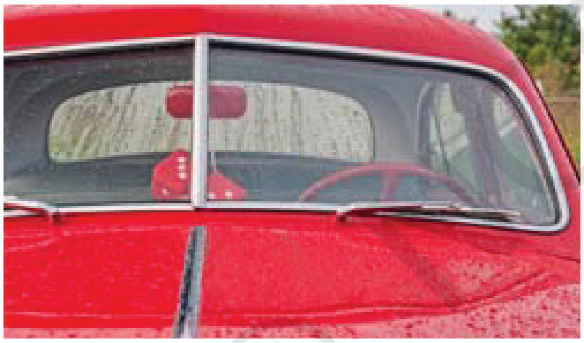


Fig. 3.9: Use of glass

Glass

Glass is used in a lot of areas of the vehicle. Obviously, its most important use is to create windshields so the driver can see properly while remaining safe from any airborne objects. It is also used to generate rear and side-view mirrors to boost view of what's around the driver while driving. However, as technology advances, glass is also being used to generate more innovative parts on vehicle. For example, it can be used to produce navigation screens and lenses for back-up cameras to allow drivers to have an even better view of what's in the wake of them.

Check Your Progress

A. Fill in the blanks

1. ___________ and ___________ contain high proportion of iron.
2. ________ is an alloy of carbon and iron.

3. Steels containing ________ to ________ carbon are called plain carbon steels.
4. Steels containing up to ________ carbon are called dead mild steel.
5. Blocks of many automobile and tractor assemblies are made of ________.

B. Multiple choice questions

1. Alloy steels containing up to 5% of total alloying elements are called ____________.
    - (a) low alloy steels
    - (b) medium alloy steel
    - (c) hard steel
    - (d) None of the above
2. Mechanical properties of alloy steel, such as yield strength, ductility, are improved by ____________.
    - (a) alloying
    - (b) welding
    - (c) quenching
    - (d) moulding
3. The material used to construct vehicle chassis and frames is ____________.
    - (a) carbon steel or aluminium alloys
    - (b) iron or chromium
    - (c) copper or steel
    - (d) mould material
4. The fast cooling of iron with 2%–4.3 % carbon produces ________________.
    - (a) white cast iron
    - (b) grey cast iron
    - (c) hard iron
    - (d) mild cast iron
5. When white cast iron cools down slowly, the resulting product is known as ______________.
    - (a) malleable cast iron
    - (b) hard iron
    - (c) grey iron
    - (d) None of the above

C. Answer the following questions

1. Differentiate between glass and rubber.
2. Explain the role of plastic in automotive industry.

SESSION 2: BASIC MANUFACTURING PROCESSES

Manufacturing is the process of turning raw materials into finished products.

There are four types of manufacturing processes, which are as follows:

1. Casting
2. Forming
3. Joining
4. Machining

Casting

Casting is one of the oldest processes of manufacturing metallic components. In this process, a liquid material, which may be ferrous or non-ferrous, is poured into a moulding, and then allowed to solidity. Casting is done using various methods, which are as follows:

- Sand casting
- Shell casting
- Investment casting
- Full moulding
- Co_2 moulding

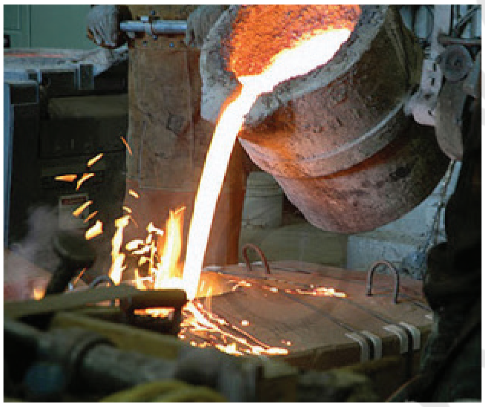


Fig. 3.10: Casting process

The mould is prepared from a refractory material like sand, etc. Fig.3.10 shows the casting process.

For bulky production of any design product, casting process is used. Important reasons for use of casting are stated here:

(a) Casting can create very composite geometry parts with hollow sections as well as cavities.

(b) It is used to construct from small to huge parts.

(c) In this process little wastage takes place and the extra metal may be re-used. It is economical as well.

Basic Casting Steps

The basic steps in making a casting are as follows:

1. Preparation of pattern and mould.
2. Melting and pouring the liquefied metal

3. Cooling and solidification of liquid metal
4. Inspecting the casting, refining and giving it final shape.

Applications of Casting Process

(a) Transport: Automobile—cylinder blocks, piston, piston ring, wheels, housing, etc.
(b) Machining and frames grind rolls,
(c) Water deliver and sewer pipes, sanitary fittings, door handles, locks, the outer casing or housing for motors, pumps and agricultural parts, etc. It is also used in the toy industry to build parts, for example, toy cars, planes, etc.

Machining

There are two types of machining processes:

- Conventional machining
- Unconventional machining

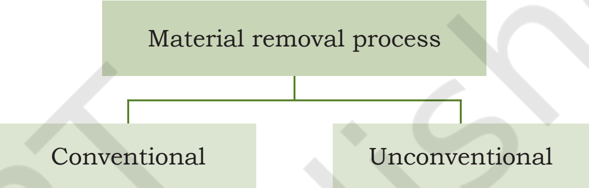


Fig. 3.11: Types of Machining

Machining is the process of cutting, shaping, or removing of material from a work piece using a machine tool.

During the manufacturing process, metal components and parts pass through machining process. Different materials like rubbers, plastic, paper goods are generally manufactured by machining processes.

All finished product meets the specifications as per engineering drawings. For example, a work piece may be required to have a specific outside diameter.

A lathe is an important machine tool used to reduce the diameter by rotating a metal piece. In this process, cutting tool cut metal and create a round surface as per the desired diameter and finish. A drill removes metal in the cylindrical shape of a hole. Various types of tools are used in milling machines for metal removal like saws, and grinding machines.

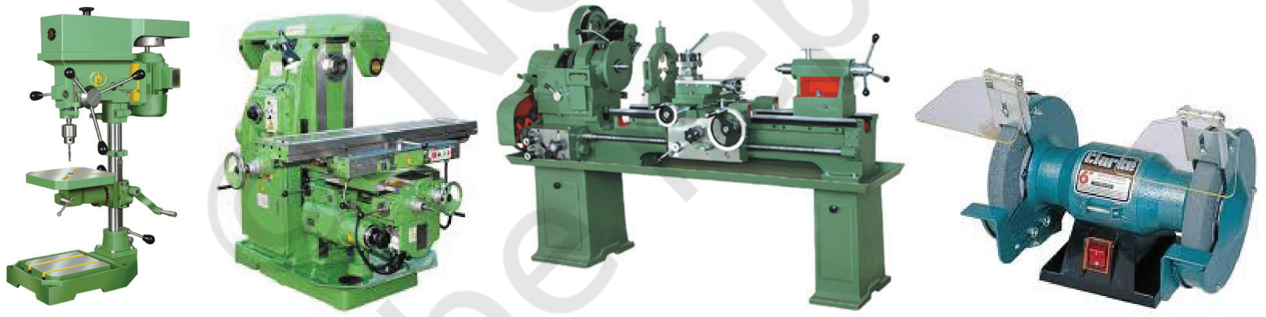
Machining Operations

Turning, drilling and milling are three important machining processes. Similarly, many operations like shaping; planning, boring, broaching and sawing are also part of machining operations.

- Turning is a type of machining or material removal process. In this process, a machine tool is used to create rotational parts by cutting away unwanted material. Lathes are the principal machine tool use in turning.
- Milling is material removal process. In this process a variety of features are created on a part by cutting away the undesired material. The milling does milling process. In milling, rotary cutters are used to remove material from a work piece.
- Drilling is a process of making a hole by oblique cutting. They are made by forging and are smaller in size so that there is some margin for reaming. Drilling is done primarily with a drill machine.
- Grinding is done to get the desired surface finish, correct size and accurate shape of product. Grinding wheel consists of abrasive particle, bonding material and voids. The abrasive surfaces act like cutting tool tips and remove the metal.

Lathe boring is a cutting operation that uses a boring head to enlarge an existing opening in a work piece. The expected accuracy of finish is +0.125mm.

Fig.3.12 shows some of the machine tools.



Drilling Machine Lathe Machine Milling Machine Grinding Machine

Fig. 3.12: Machine tools

Forming

Forming is the method in which the required size and shape are obtained through plastic deformation of a material. Aluminium or steel, coins, frame of doors and windows, springs, elevator doors, cables and wires, sheet-metal, etc., are made through the forming process.

Rolling

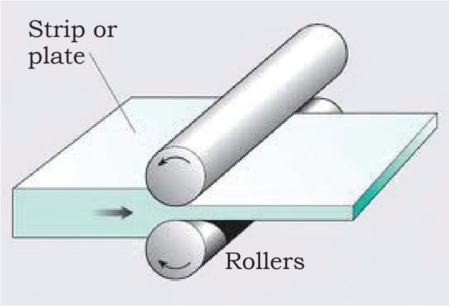


Fig. 3.13: Rolling process

Rolling is a metal forming process. The process includes shape rolling, flat rolling, ring rolling, thread rolling, gear rolling, etc. In this process, a seamless tube and pipe are produced by rotary tube piercing or roll piercing. The material is drawn between the two revolving roll gaps by means of friction. All the sections of steels, such as channel, I-section, channel section, angle sections, flat iron, sheets, etc., are produced by the rolling process and many of them are used in developing vehicle chassis and body. Fig.3.13 shows a simple flat rolling process.

Forging

When the metal is heated and a force is applied to metal to achieve final shape it is called forging.

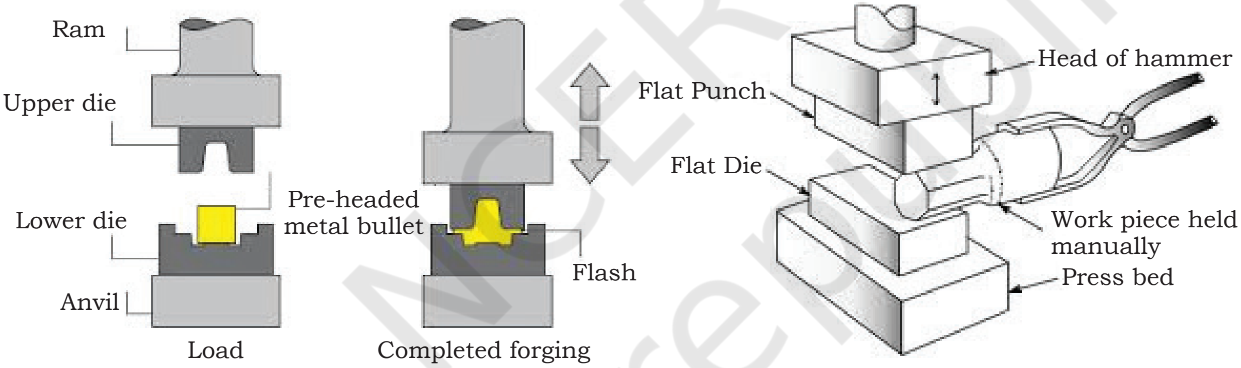
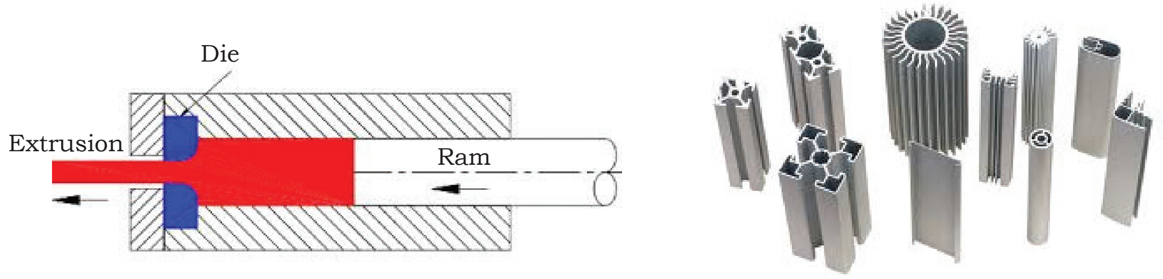


Fig. 3.14: Forging process

There are two types of forging—hot and cold. Auto components made using forging include crankshaft, camshaft, connecting rod, tie rod ends, ball joints, transmission gears, idler arms, drag links, rear axle shaft, propeller shaft components, steering cross assembly, clutch forks, water pump parts, etc. Fig.3.14 shows the forging process.

Extrusion

When a metal is extracted through a closed cavity to obtain a desired shape, it is known as extrusion. The shape of cross-sections can be solid round, rectangular, L-shapes, T-shapes and tubes. Fig.3.15 shows the extrusion and extruded products.



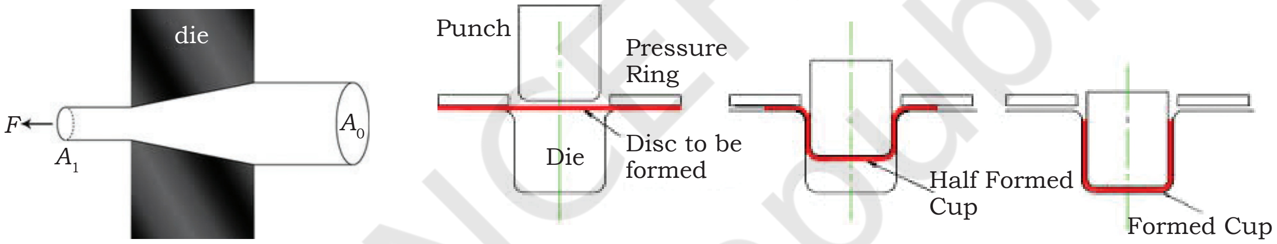
Extrusion

Aluminium extruded products

Fig. 3.15: Extrusion process

Drawing

It is a metal working process, which uses tensile forces to stretch metal or glass. As the metal is pulled through a dice then it stretches into a desired shape and thickness. Drawing process is used to make wire rods, tubes and sections.



Drawing

Deep Drawing

Fig. 3.16: Drawing process

Joining Processes

Joining processes are those processes that are used for joining metal parts and metal fabrication work. They are of four types: (a) Welding (b) Soldering (c) Brazing and (d) Adhesive Bonding.

Welding

Welding is the process of joining a similar and dissimilar material. In this process, two parts are joined together under heat or pressure with or without added metal. The welding process is divided into two categories, plastic welding or pressure welding and fusion welding or non-pressure welding, respectively.

Oxy-acetylene welding

Oxy-Fuel gas-Welding- is also called OFW. In this welding, Acetylene and oxygen gases are mixed; this generates very high temperatures of up to 3000°C. The flame helps in melting the metal at the joint, along with a filler rod to supply a number of additional materials to fill the gap. The flame is applied to the base metal and held until a small puddle of molten metal is formed. The oxy-acetylene welding process is shown in Fig.3.17. OFW is used to join mild steel permanently.

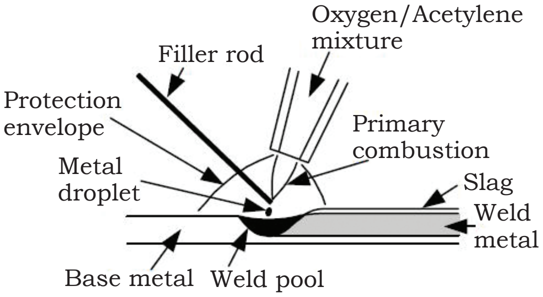


Fig. 3.17: Oxy-acetylene welding

Arc welding

Arc welding is one of the fusion processes for joining metals. In arc welding, intense heat is used to melt metal. Heat is produced by an electric arc. The arc is formed between the actual work and an electrode. This is also called the stick electrode welding procedure. Another name of this welding procedure is the coated electrode welding procedure. The usual diameter of the electrode is 2.5 to 6.35 mm, and the length of the electrode is 300 to 450 mm. Constant current type power source is used. First, the arc is generated in between the electrode and the work-piece. The temperature of the core and in between the arc is in the range of the 6000–7000 °C. If the movement of the arc or the electrode is controlled by machine, then it is called automatic arc welding. And if the first movement of the electrode is control by the machine then it is called as the semi-automatic machine. This welding can be done with both AC or DC type of current. Fig.3.18 shows an arc-welding circuit.

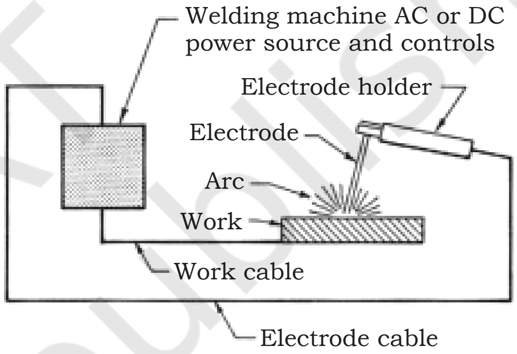


Fig. 3.18: Basic arc welding circuit

Check Your Progress

A. Fill in the blanks

1. Pouring of ______________ into a mould is called casting.
2. The processing of raw material or parts into finished goods with the use of tool is called ______________.

3. ______________ is the process of removing undesired material from a work piece.
4. In milling ______________ are used to remove material from a work piece.
5. ______________ is done to get desired surface finish, correct size and accurate shape of product.

B. Multiple choice questions

1. In which method is the required size and shape obtained through plastic deformation of a material?
   (a) Forming
   (b) Machining
   (c) Honing
   (d) Welding
2. All the sections of steels, such as channel, I-section, channel section, angle sections, flat iron, sheets, etc., are produced by ____________.
   (a) rolling
   (b) welding
   (c) moulding
   (d) casting
3. Auto components like crankshaft, camshaft, connecting rod, tie rod ends, ball joints, are prepared by _____________.
   (a) forging
   (b) forming
   (c) extrusion
   (d) drawing
4. When a metal is extracted through a closed cavity to obtain desired shape of metal that process is called ________________.
   (a) extrusion
   (b) forming
   (c) welding
   (d) moulding
5. The process of joining the similar and dissimilar material is called ______________.
   (a) welding
   (b) drawing
   (c) casting
   (d) None of the above

C. Answer the following questions

1. Differentiate between rolling and forming.
2. Explain the different types of joining processes.